

ABSTRACT

Weather routing of ships is an important consideration in ship navigation, which is essentially concerned with establishing an optimal route (the most economical route) from a departure to arrival point by applying available information of the weather condition viz. wind, wave and current along with the behaviour of ship. This thesis addresses the problem of minimal (optimum) time route by applying optimal control theory in conjunction with hydrodynamics and weather forecasting tools.

Information on ship speed loss due to weather condition effects is pre-computed using seakeeping computing tools which are then suitably employed in the optimum ship routing algorithm. Wave forecasts are provided in a deterministic setting by a third generation numerical wave model WAM. Dijkstra's path optimization scheme, which employs optimal control theory and dynamic programming technique, is used to obtain optimum route in a given random sea-state. The concept of an 'objective function' or the weight-function used in optimization techniques, which needs to be minimized in the context of the optimization algorithm, is described. For minimum-time route, suitable approximate expressions are made for determining the reduced speed after taking into account the environmental factors.

The developed algorithm is investigated through various realistic wave information (i.e. wave height and wave direction) obtained from WAM. Illustrative minimum time sea routes on Arabian Sea and Bay-of-Bengal for different ships have been determined and presented. All relevant practical and realistic constraints such as presence land boundaries, avoiding non-navigable water, effects of wind and current, voluntary speed reduction (with various safety constraints) etc. are also incorporated within the framework of the algorithm.

The problem formulation adopted in this thesis lies in the framework of Dynamic Programming (DP), which is most suitable for computer implementation. By utilizing the hydrodynamic results (i.e. various resistance and safety constraints) and weather information (i.e. outputs from wave model) a computer code is developed in 'C/C++', which employs the iterative DP procedure to solve the optimal control problem. Outputs of this numerical procedure are plotted through "ArcGis3.2" to show various ocean routes used in this thesis.

It is concluded that the developed algorithm is capable of generating optimal route for realistic ship navigation operations by taking into account all practical constraints. Although presently only minimal-time routing is considered, the algorithm is general enough to consider other any other optimization parameters provided a suitable weight function can be formed.

Keywords: Ship behaviour, WAM, Seakeeping, Dijkstra's, Optimization, Indian Ocean